

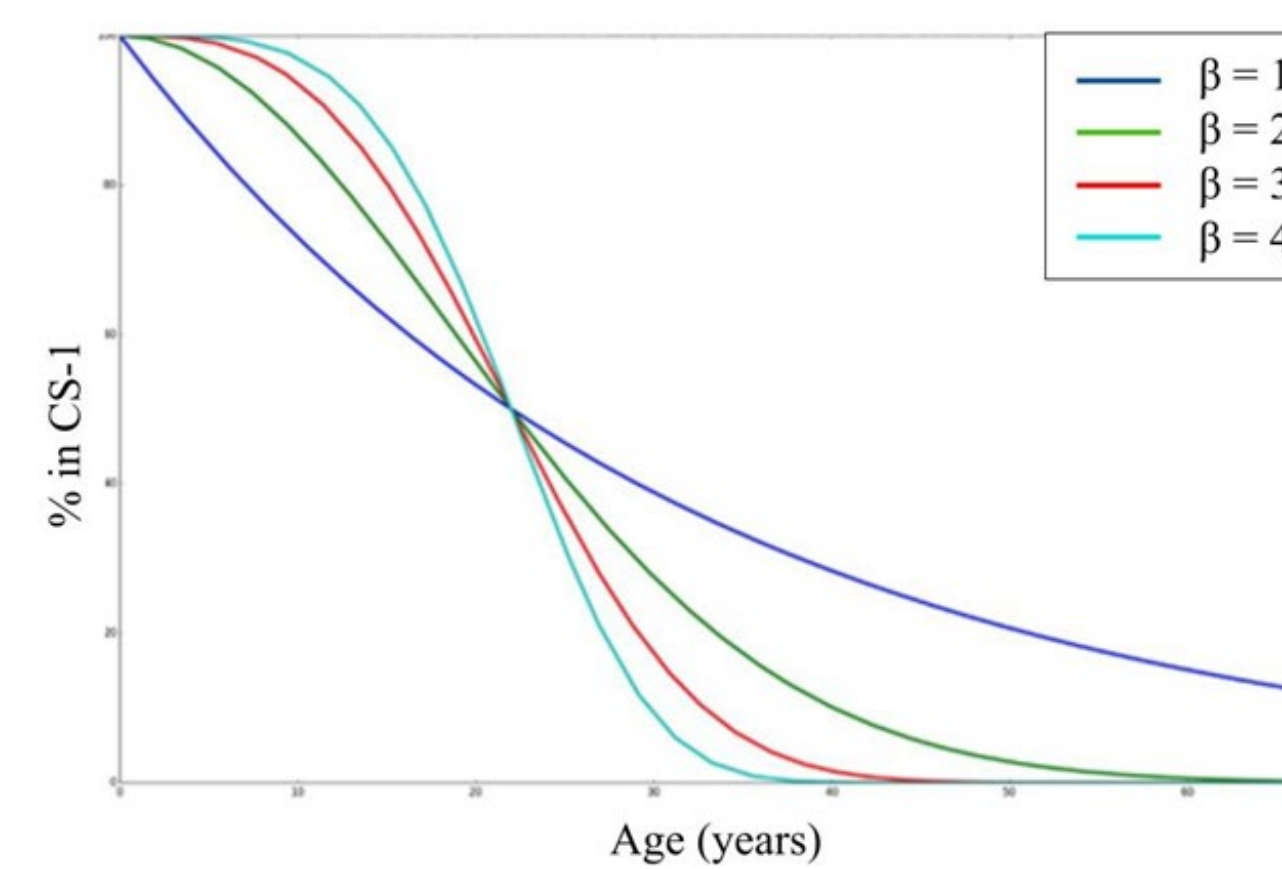
Background

AASHTOWare Bridge Management Software (BrM)

- Weibull distribution used to model deterioration from CS-1 to CS-2.

Parameters

- shape factor = β .
- median years in CS-1.

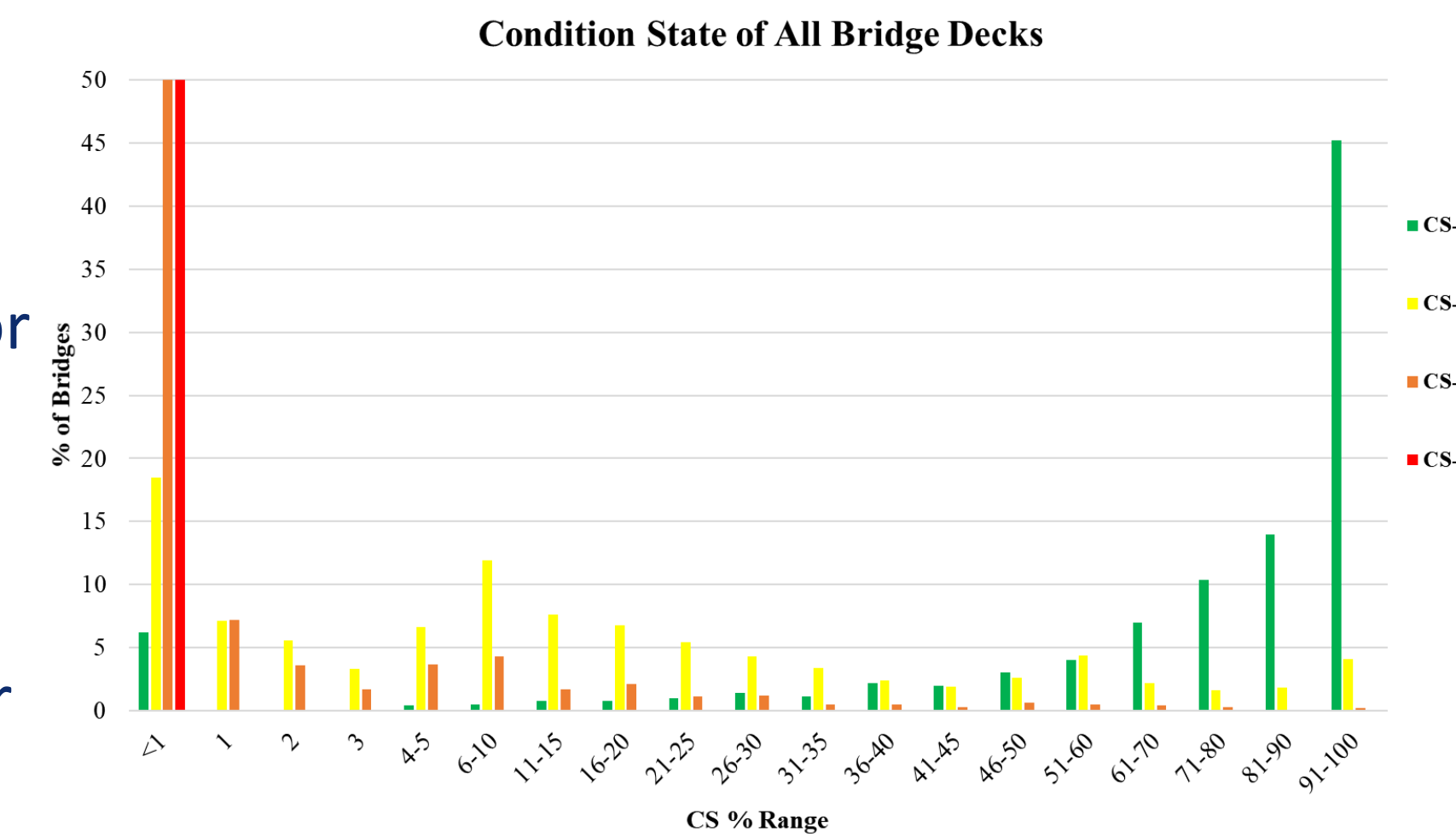


- Default parameters used in BrM = average of values from Alabama, Idaho, New York, California, and Kentucky.

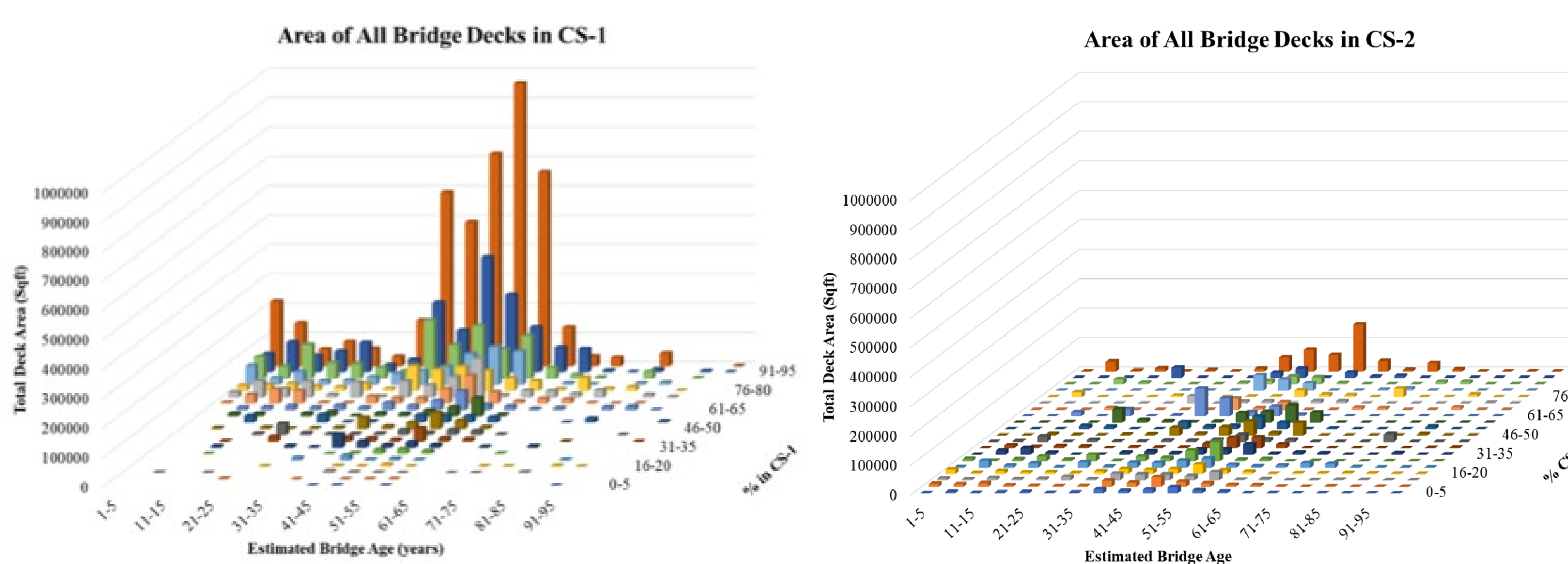
Parameter Estimates	Shape Factor	Median Years		
		CS-1	CS-2	CS-3
BrM Default	1.3	14.4	42	14.9

Percent of bridge decks in CS-1, 2020

- Median percentage of bridge deck area rated as CS-1 was 75%.
- Median percentages for CS-2 and CS-3 were 22% and 3%, respectively.
- Research focus was Weibull distribution for CS-1 deterioration.



Raw data for bridge deck CS-1 and CS-2 ratings

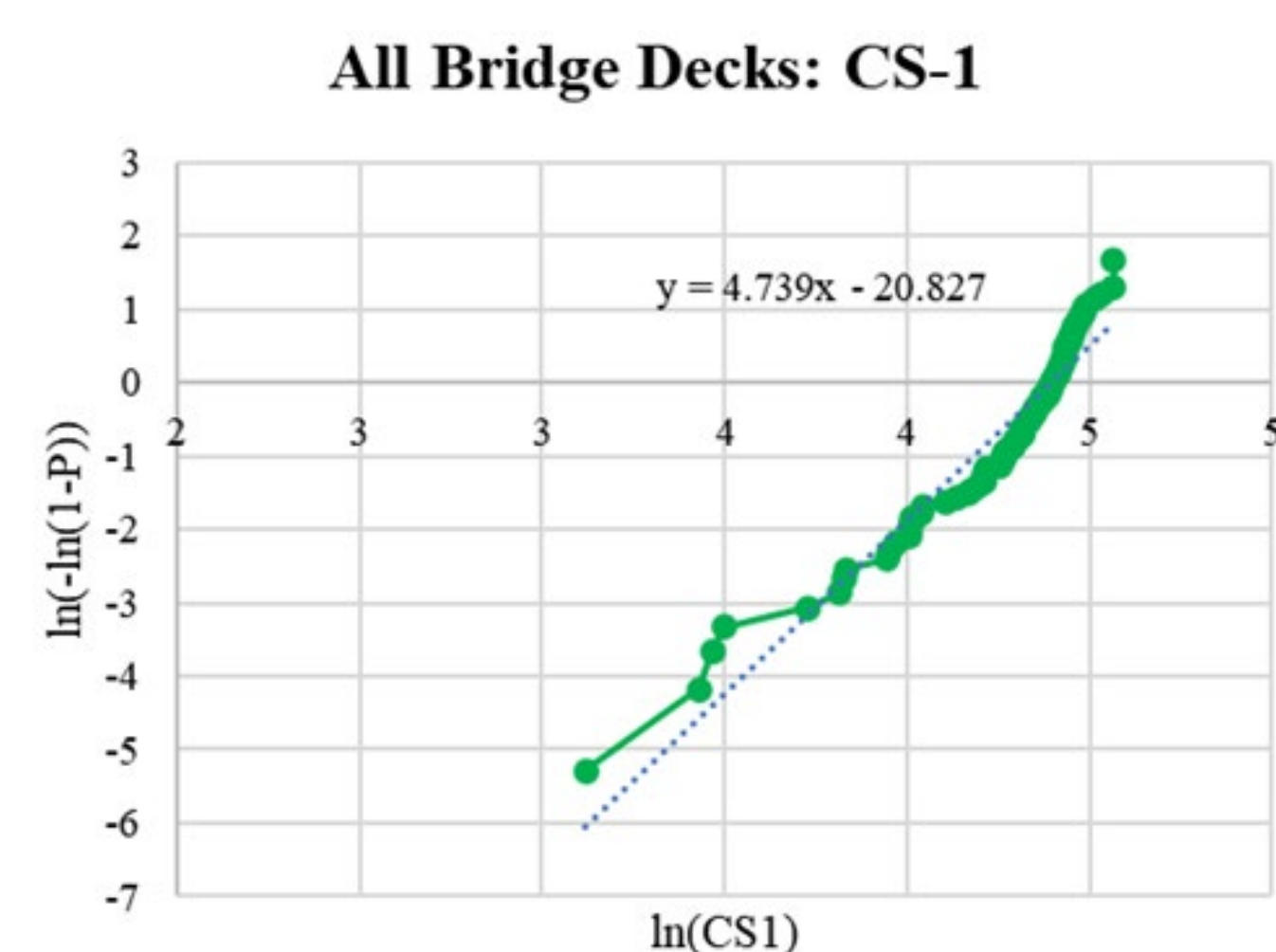


Statistical Analysis: Weibull Distribution using Graphical Method

- Focused on transition from CS-1 to CS-2.
- Uses all years of inspection data
- BrM input parameters.

$$y = \beta [-\ln(x)]^{1/\alpha} \quad \text{median years} = \alpha (\ln 2)^{1/\alpha}$$

β = Shape factor α = Scale factor



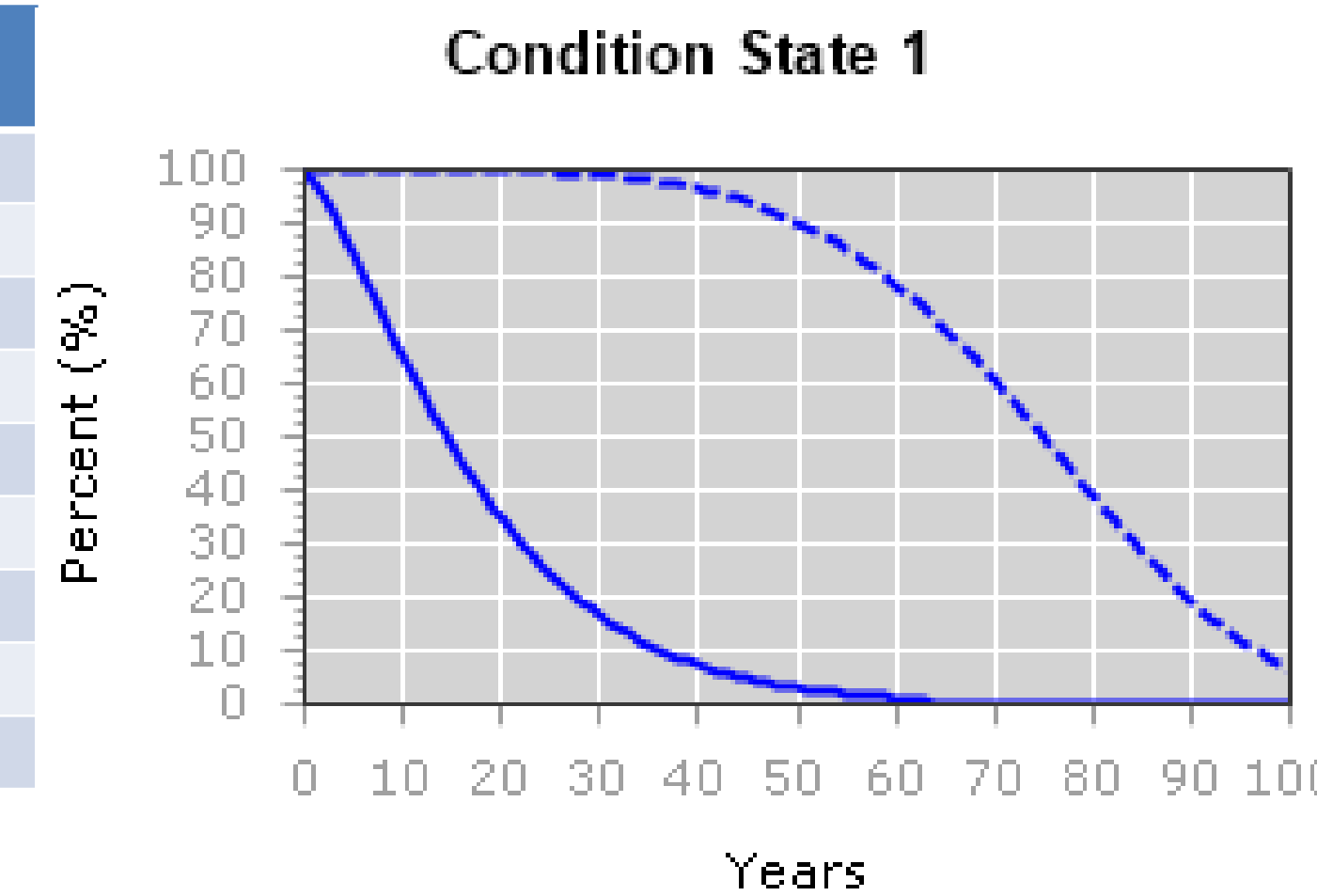
- Adjustments made to calculated parameters to better represent deterioration targets.

Approach

Estimated deterioration targets

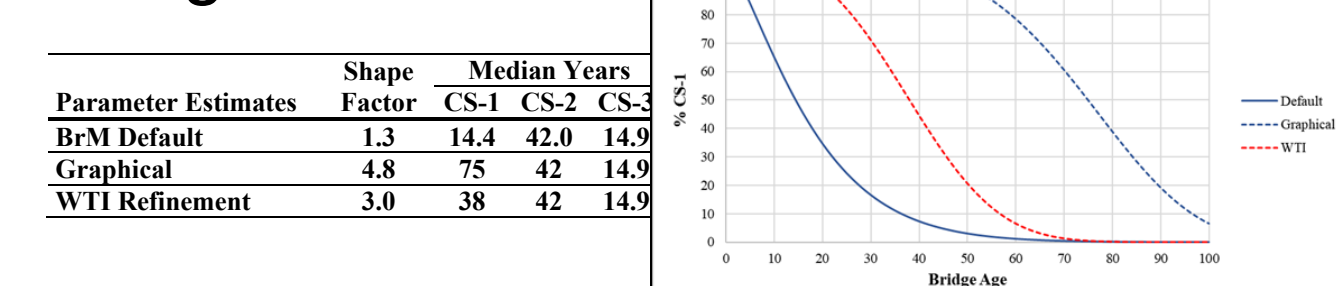
Element	CS-1 Target	Years
Reinforced Concrete Deck	97.5%	10
Steel Girder	90%	20
Prestressed Concrete Girder	70%	30
Concrete Abutment	90%	50
Steel Culverts	75%	50
Concrete Culvert	95%	30
Concrete Culvert	75%	50

Default vs. calculated deterioration curves

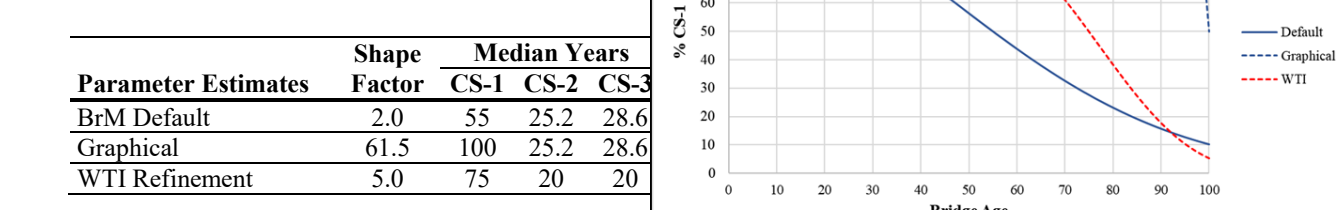


Results

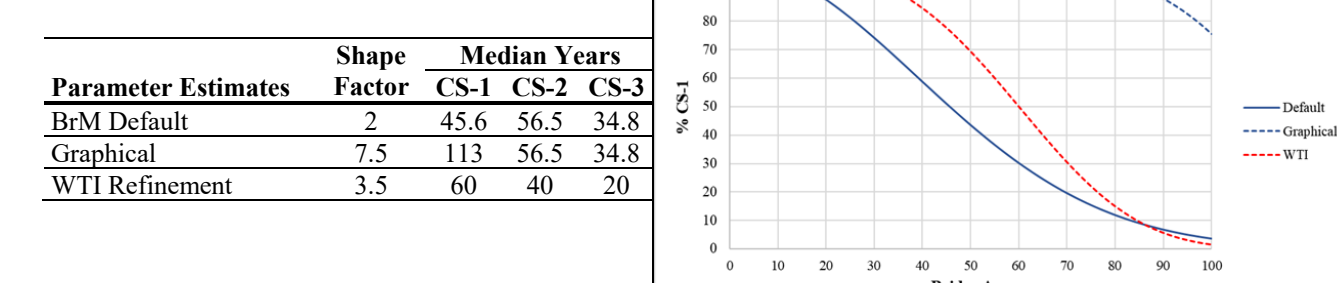
Bridge Decks



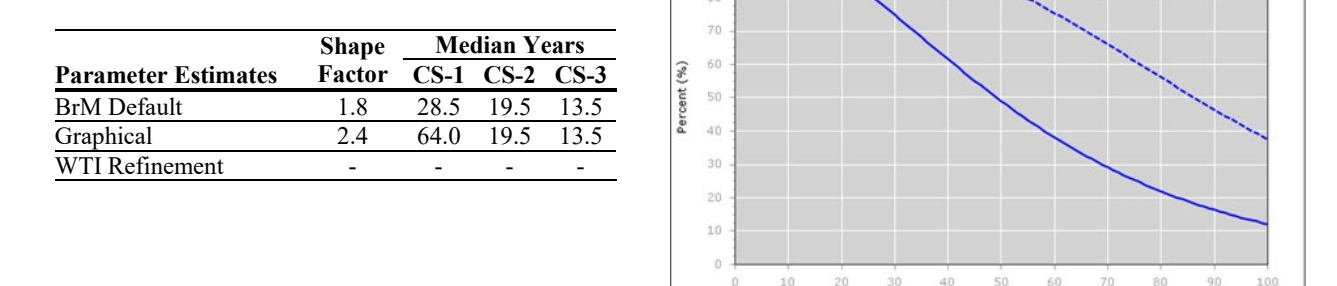
Prestressed Concrete Girders



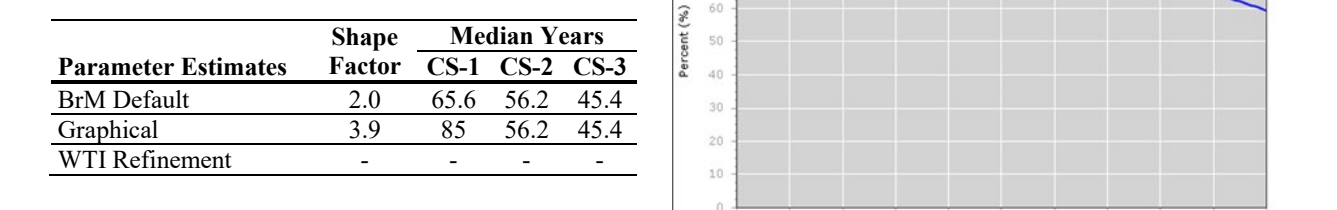
Concrete Culverts



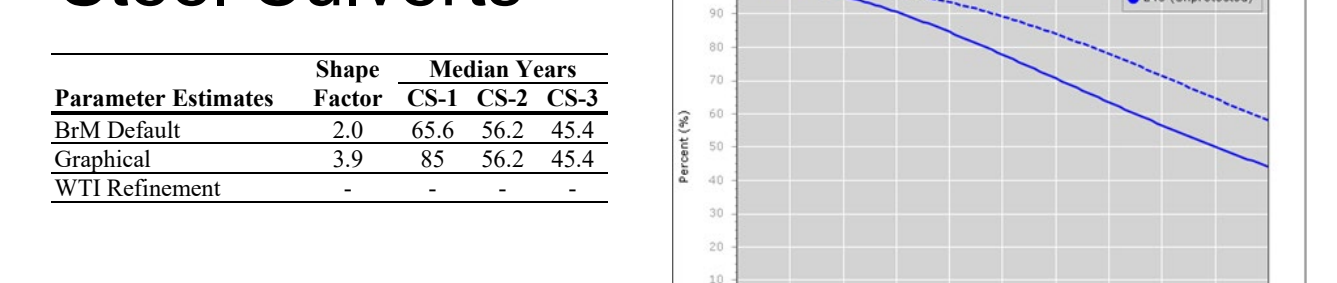
Steel Girders



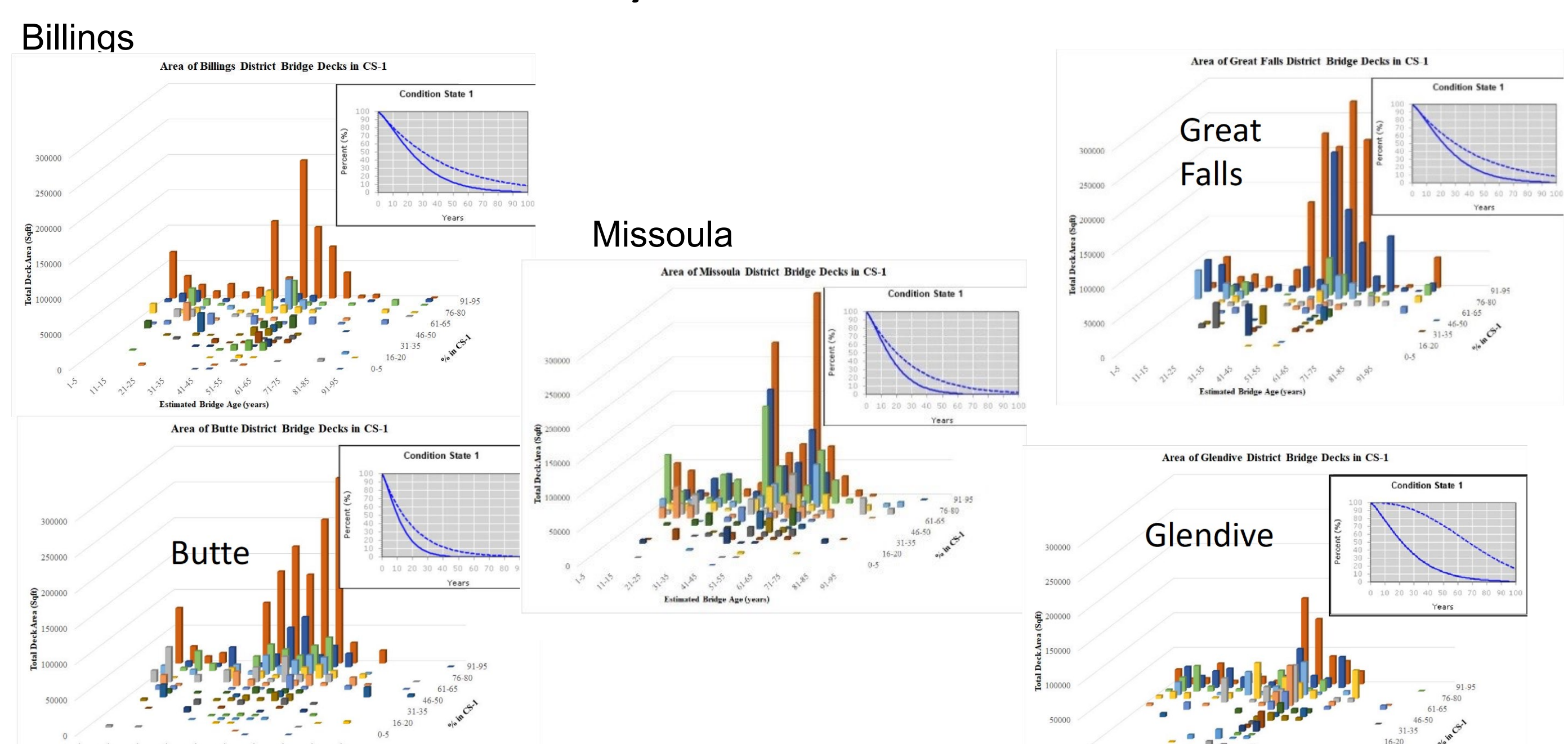
Concrete Abutments



Steel Culverts



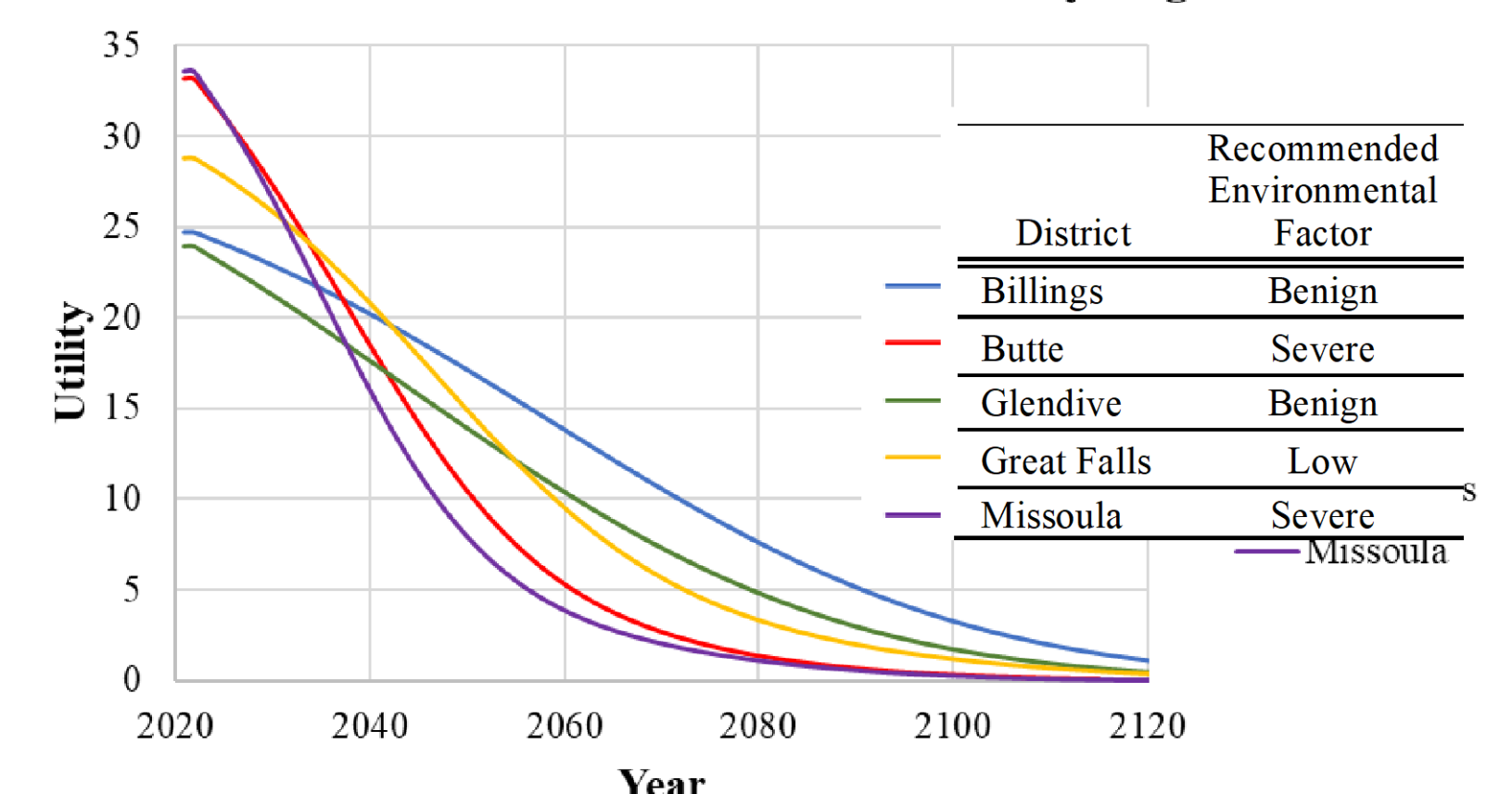
Deterioration trends by maintenance district



Environmental factors

- Shape-factors and median years in CS-1 for calculated for each maintenance district.
- Utility index = customized deterioration curve that considers user-defined elements and condition state ratings.
- Shown here are concrete deck elements and CS-1 deterioration.

Concrete Deck Deterioration Rates by Region



Optimization Analysis



BrM Health Index Detailed Calculation

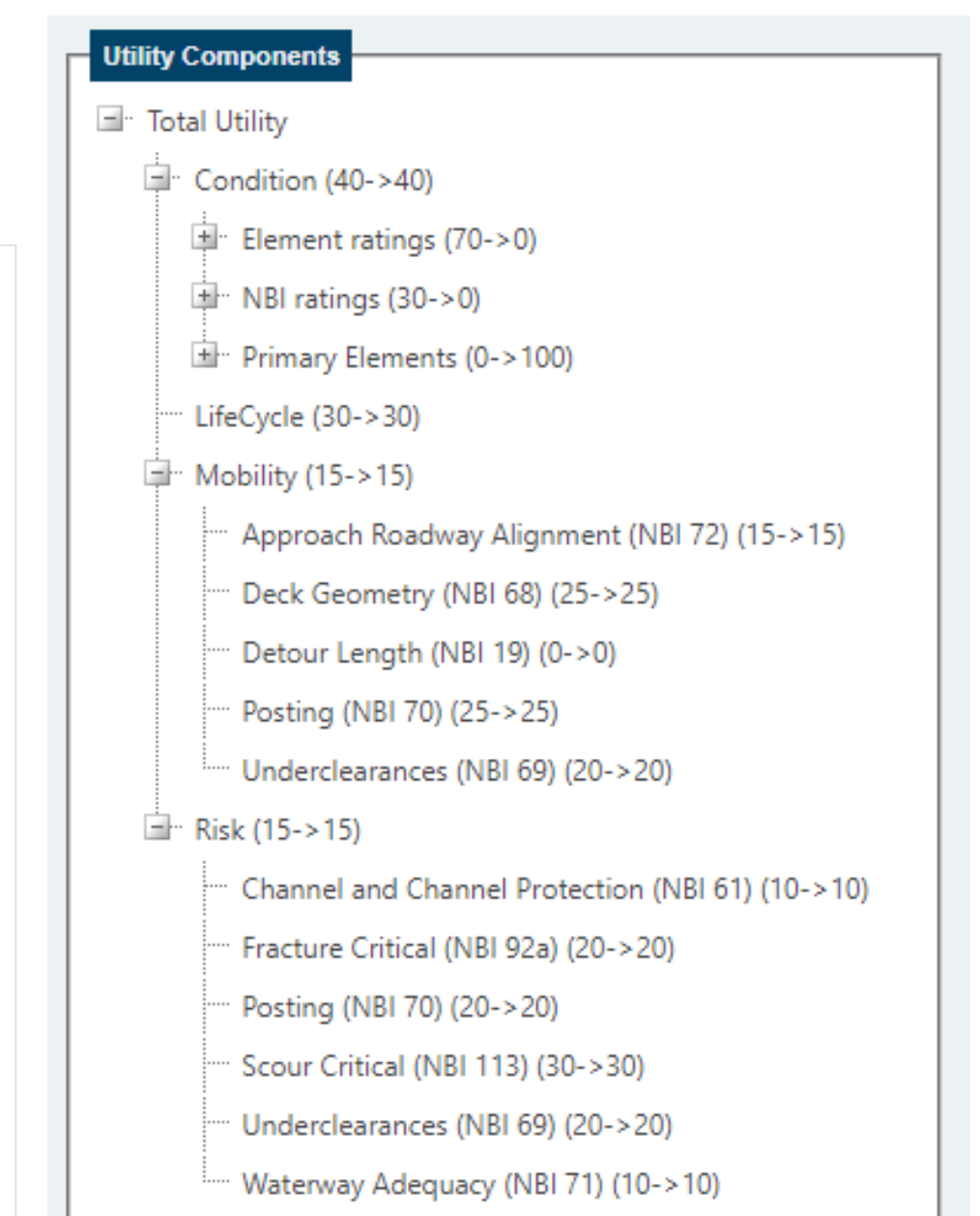
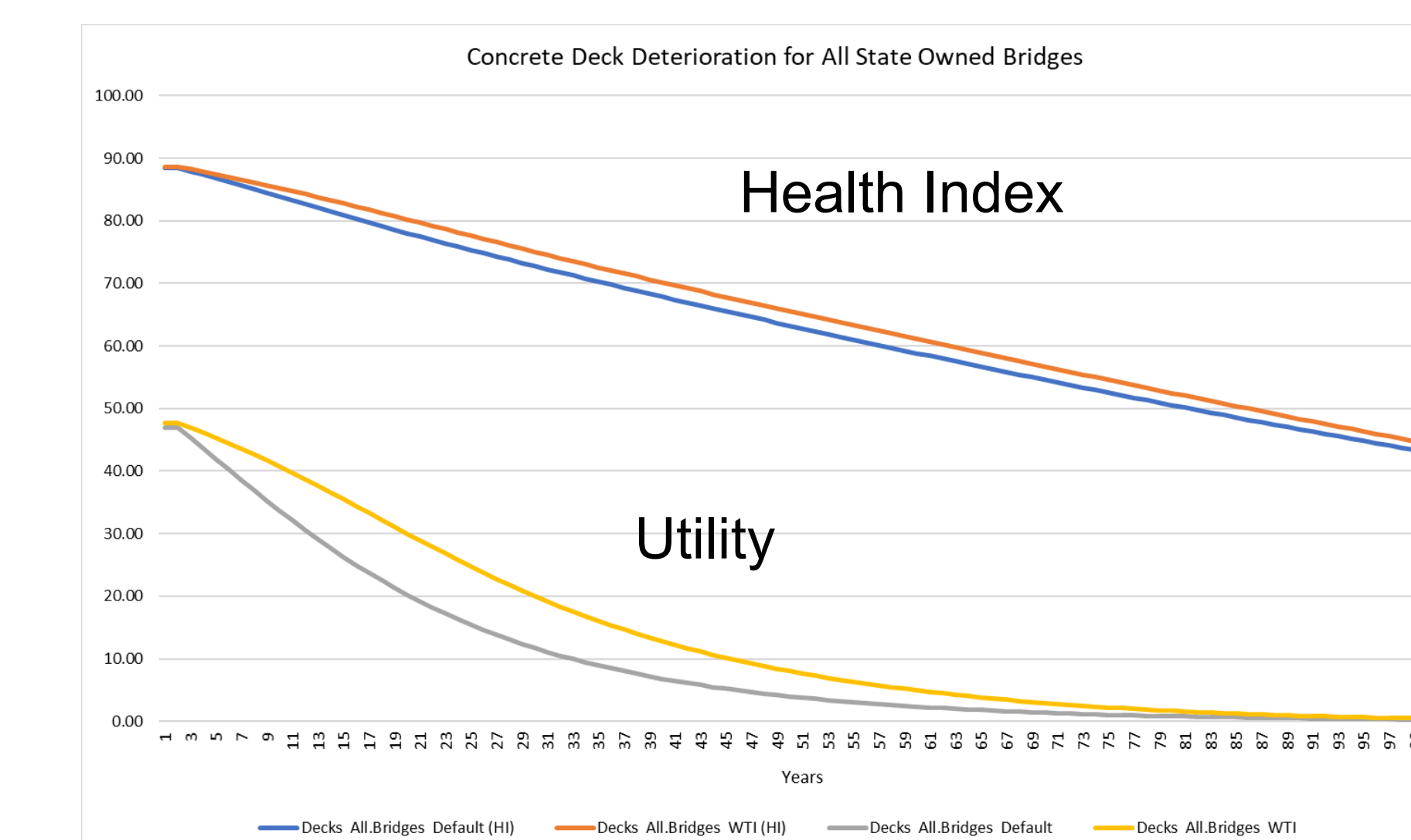
This report exemplifies the values and factors used to determine the Health Index for a particular structure. The elements and quantities for a given structure are modified on the Inspection > Condition page, and the factors and weights for an element are modified on the Admin > Modeling Config > Element Defs page. Defects and protective systems are not included.

$$HI = \frac{\sum_{All\ Elements} W_E \left(\sum_{CS1}^{CS4} C_n Q_n \right)}{\sum_{All\ Elements} W_E Q_{Total}}$$

Where:
 HI = the Health Index, a measure of remaining health, 0% to 100%
 W = the relative weight of an element
 C = the condition state coefficient, between 1 and 0
 Q = Quantity in a condition state or Quantity Total, from inspection data

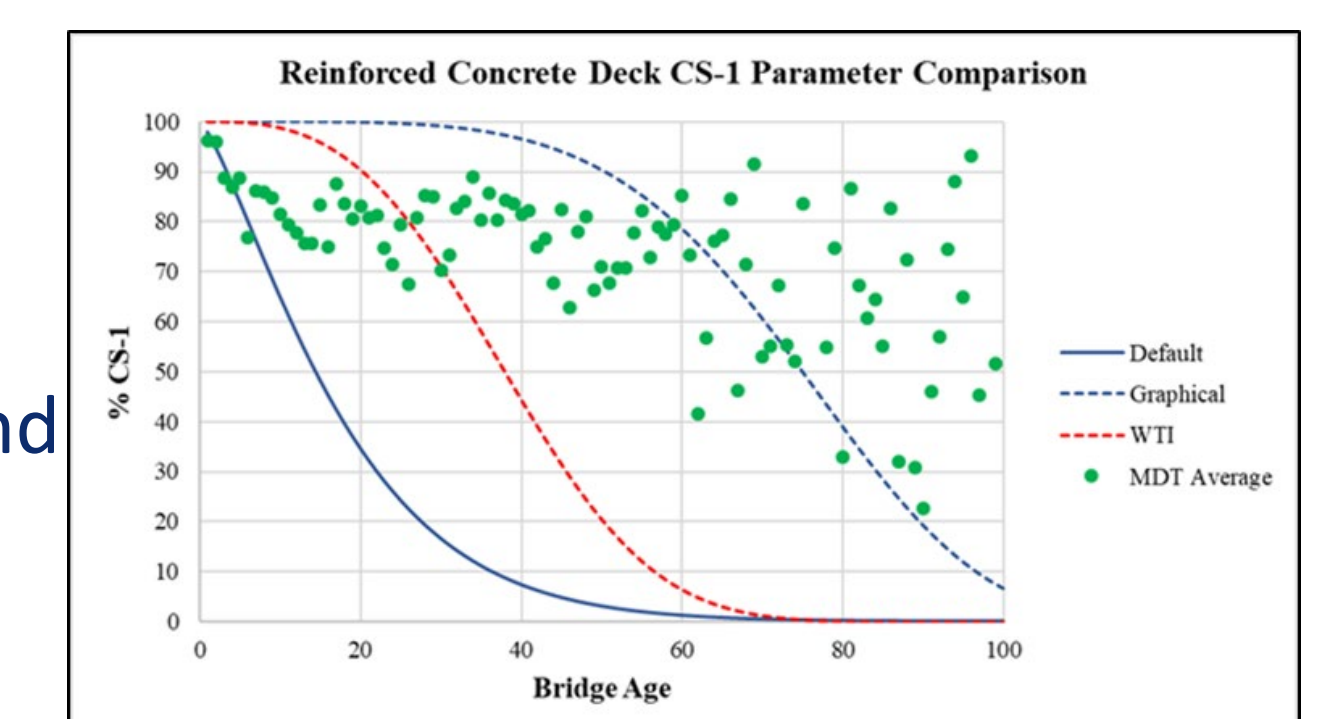
- Coefficients: CS-1 = 1.0, CS-2 = 0.67, CS-3 = 0.33, CS-4 = 0.
- Calculated for each bridge and averaged for multi-bridge dataset.
- No-cost optimization analysis.

Concrete deck, all bridges



Summary of Results

- Calculated deterioration curves better represent the bridges in Montana compared to the BrM default values.
- Further adjustments made for bridge decks, prestressed concrete girders, and concrete culverts.
- Environmental factors identified for all five of the MDT maintenance districts.



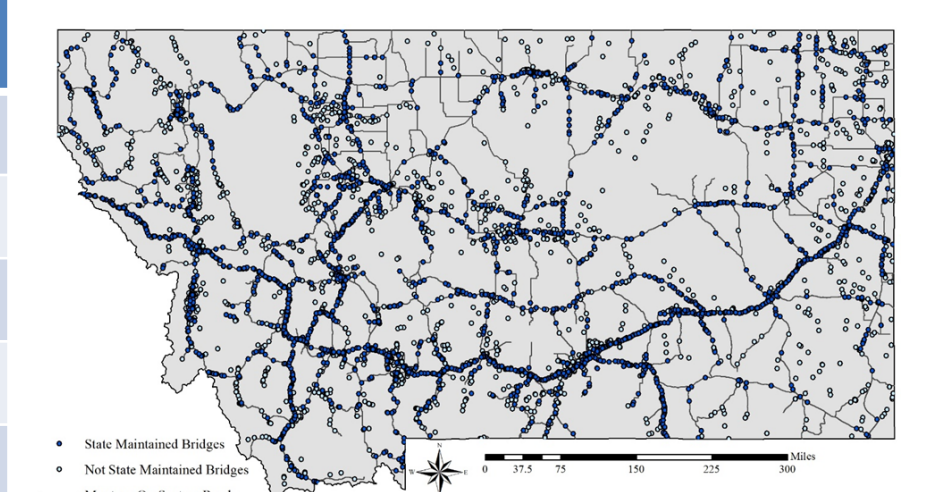
Conclusions

Recommended BrM Input Parameters

Element	BrM Defaults				Graphical Method		WTI Refined Values			
	β	CS-1	CS-2	CS-3	B	CS-1	B	CS-1	CS-2	CS-3
Concrete decks	1.3	14.4	42	14.9	4.8	75	3	38	42	14.9
Steel girder	1.8	28.5	19.5	13.5	2.4	64	2.4	64	19.5	13.5
Concrete girder	2	55	25.2	28.6	61.5	100	5	75	20	20
Concrete Abutment	2	65.6	56.2	45.4	3.9	85	3.9	85	56.2	45.4
Steel culvert	1.8	51.5	33.1	39.1	2.3	74	2.3	74	33.1	39.1
Concrete culvert	2	45.6	56.5	34.8	7.5	113	3.5	60	40	20

Environmental Factors

Region	Graphical-Method Shape Factor (β)	Recommended Environment	BrM Environment Factor
State-wide	4.8	Moderate	1.0
Billings	3.8	Benign	2.0
Butte	3.2	Severe	0.7
Glendive	5.0	Benign	2.0
Great Falls	6.5	Low	1.5
Missoula	6.5	Severe	0.7



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